

Claims

We claim:

1. An electrochemical structure within an integrated circuit, comprising:

a semiconductor wafer;

a layer of electronic devices on the semiconductor wafer, wherein the layer of electronic devices includes at least one electronic device;

N wiring levels on the layer of electronic devices, wherein N is at least 1, wherein the N wiring levels are denoted as wiring level 1, wiring level 2, ..., wiring level N, and wherein the N wiring levels include a first conductive metallization and a second conductive metallization; and

at least one battery within the wiring levels I through K, wherein I is selected from the group consisting of 1, 2, ..., and N, wherein K is selected from the group consisting of I, I+1, ..., and N, wherein the first conductive metallization conductively couples a first electrode of the at least one battery to the at least one electronic device, and wherein the second conductive metallization conductively couples a second electrode of the battery to the at least one electronic device.

2. The electrochemical structure of claim 1, wherein the N wiring levels and the at least one battery are formed during a Back-End-Of-Line (BEOL) integration of the integrated circuit.

3. The electrochemical structure of claim 1, wherein the at least one battery includes a plurality of batteries in series.

1 4. The electrochemical structure of claim 3, wherein the batteries in series consist of U-Batteries
2 in series.

1 5. The electrochemical structure of claim 3, wherein the plurality of batteries includes M
2 batteries denoted as batteries 1, 2, ..., M, wherein M is at least 2, wherein each battery L is in
3 series with battery L+1 and is conductively coupled to battery L+1 by a conductive interconnect,
4 and wherein L = 1, 2, ..., M-1.

1 6. The electrochemical structure of claim 3, wherein the plurality of batteries includes M
2 batteries denoted as batteries 1, 2, ..., M, wherein M is at least 2, wherein each battery L is in
3 series with battery L+1 and is conductively coupled to battery L+1, wherein there is no
4 conductive interconnect between battery L and battery L+1, and wherein L = 1, 2, ..., M-1.

1 7. The electrochemical structure of claim 1, wherein the at least one battery includes a plurality
2 of batteries in parallel.

1 8. The electrochemical structure of claim 1, wherein the first conductive metallization includes a
2 first conductor that conductively contacts the first electrode, wherein second conductive
3 metallization includes a second conductor that conductively contacts the second electrode,
4 wherein the first conductor is within the wiring levels I, I+1, ... K, and wherein the second
5 conductor is within the wiring levels I, I+1, ... K.

1 9. The electrochemical structure of claim 8, wherein K = I.

1 10. The electrochemical structure of claim 1, wherein the first conductive metallization includes
2 a first conductor that conductively contacts the first electrode, wherein second conductive
3 metallization includes a second conductor that conductively contacts the second electrode,
4 wherein the first conductor is outside of the wiring levels I, I+1, ... K, and wherein the second
5 conductor is outside of the wiring levels I, I+1, ... K.

1 11. The electrochemical structure of claim 1, wherein the at least one battery includes a first
2 battery, wherein an anode of the first battery includes an anode material selected from the group
3 consisting of lithium, lithiated vanadium oxide ($\text{Li}_8\text{V}_2\text{O}_5$), AgI, Ag, and Zn, and wherein a
4 cathode of the first battery includes a cathode material selected from the group consisting of
5 V_2O_5 , LiMn_2O_4 , LiCoO_2 , Sn, Pb, and Ag, and wherein an electrolyte of the first battery includes
6 lithium phosphorous oxynitride.

1 12. The electrochemical structure of claim 1, wherein the at least one battery includes a U-
2 Battery.

1 13. The electrochemical structure of claim 12, wherein the U-Battery is selected from the group
2 consisting of a U-Battery With Double Extension.

1 14. The electrochemical structure of claim 1, wherein the at least one battery includes a S-
2 Battery.

1 15. A method for forming an electrochemical structure within an integrated circuit, comprising
2 the steps of:
3 providing a semiconductor wafer;
4 forming a layer of electronic devices on the semiconductor wafer, wherein the layer of
5 electronic devices includes at least one electronic device;
6 forming N wiring levels on the layer of electronic devices, wherein N is at least 1,
7 wherein the N wiring levels are denoted as wiring level 1, wiring level 2, ... , wiring level N;
8 forming a first conductive metallization and a second conductive metallization within the
9 N wiring levels; and
10 forming at least one battery within the wiring levels I through K, wherein I is selected
11 from the group consisting of 1, 2, ..., and N, wherein K is selected from the group consisting of I,
12 I+1, ..., and N, wherein the first conductive metallization conductively couples a first electrode of
13 the at least one battery to the at least one electronic device, and wherein the second conductive
14 representation conductively couples a second electrode of the battery to the at least one electronic
15 device.

1 16. The method of claim 15, wherein forming at least one battery includes forming a first battery,
2 comprising:

3 forming an exposed insulating layer in the wiring level I and an exposed first conductive
4 layer in the insulating layer;

5 forming an inter-level dielectric (ILD) layer over the exposed first conductive layer and
6 over the exposed insulating layer;

7 forming a first trench within the ILD layer by removing a portion of the ILD layer, which

8 exposes a portion of the first conductive layer;

9 conformally depositing an electrolyte layer over the ILD layer, over sidewalls of the first
10 trench, and within the first trench over the first conductive layer, wherein a second trench is
11 formed and is bounded by the electrolyte layer;

12 depositing a second conductive material in the second trench and on the electrolyte layer,
13 wherein the second conductive material overfills the second trench; and

14 polishing off top portions of the electrolyte layer and the second conductive material
15 resulting in a planarized top surface of the electrolyte layer and the second conductive material,
16 wherein a U-battery has been formed from the first conductive layer as the first electrode, the
17 electrolyte layer as an electrolyte, and the second conductive material as the second electrode.

1 17. The method of claim 16, wherein the first electrode is selected from the group consisting of
2 an anode and a cathode;

3 wherein if the first electrode is an anode, then the second electrode is a cathode, the first
4 conductive layer includes an anode material, and the second conductive material includes a
5 cathode material; and

6 wherein if the first electrode is a cathode, then the second electrode is an anode, the first
7 conductive layer includes a cathode material, and the second conductive material includes an
8 anode material.

1 18. The method of claim 17, wherein the anode material is selected from the group consisting of
2 lithium, lithiated vanadium oxide ($\text{Li}_8\text{V}_2\text{O}_5$), AgI, Ag, and Zn, and wherein the cathode material
3 is selected from the group consisting of V_2O_5 , LiMn_2O_4 , LiCoO_2 , Sn, Pb, and Ag, and wherein an
4 electrolyte of the first battery includes lithium phosphorous oxynitride.

1 19. The method of claim 16, wherein forming an ILD layer over the exposed first conductive
2 layer and over the exposed insulating layer comprises: forming an etch stop layer on the exposed
3 first conductive layer and on the exposed insulating layer, and forming the ILD layer on the etch
4 stop layer; and

5 wherein forming a first trench within the first ILD layer further comprises removing a
6 portion of the etch stop layer to expose the portion of the first conductive layer.

1 20. The method of claim 16, further comprising after forming a first trench: conformally
2 depositing a conductive diffusion barrier film on the ILD layer, on sidewalls of the first trench,
3 and on the exposed portion of the first conductive layer, and wherein the step of conformally
4 depositing an electrolyte layer comprises depositing the electrolyte layer on the diffusion barrier.

1 21. The method of claim 16, further comprising after forming a first trench: conformally
2 depositing a diffusion barrier film on the ILD layer, on sidewalls of the first trench, and on the
3 exposed portion of the first conductive layer; and removing the diffusion barrier film that exists
4 on the exposed portion of the first conductive layer, wherein the step of conformally depositing
5 an electrolyte layer comprises depositing the electrolyte layer on the diffusion barrier film and
6 within the first trench over the first conductive layer.

1 22. The method of claim 16, wherein forming a first conductive metallization and a second
2 conductive metallization comprises:

3 forming a composite ILD layer on the planarized top surface; and

4 forming a composite trench within the composite ILD layer, which exposes a portion of
5 the second conductive material; and

6 overfilling the composite trench with a third conductive material, wherein the third
7 conductive material conductively contacts the second conductive material; and

8 polishing off a top portion of the third conductive material, which forms a planarized top
9 surface of the third conductive material and which forms a conductive contact made of the third
10 conductive material, wherein the first conductive metallization or the second conductive
11 metallization includes the conductive contact.

1 23. The method of claim 15, wherein forming at least one battery includes forming a first battery,
2 wherein forming a first battery, forming a first conductive metallization, and forming a second
3 conductive metallization comprises:

4 forming an exposed insulating layer in the wiring level I and an exposed conductive plate
5 in the insulating layer;

6 forming an inter-level dielectric (ILD) layer over the exposed conductive plate and over
7 the exposed insulating layer;

8 forming a first trench within the ILD layer by removing a portion of the ILD layer, which
9 exposes a portion of the first conductive plate;

10 conformally depositing a first conductive layer on the ILD layer, on sidewalls of the first
11 trench, and on the exposed portion of the first conductive plate, wherein a second trench is

12 formed and is bounded by the first conductive layer;
13 conformally depositing an electrolyte layer on the first conductive layer, wherein a third
14 trench is formed and is bounded by the electrolyte layer;
15 depositing a second conductive material in the third trench and on the electrolyte layer,
16 wherein the second conductive material overfills the third trench; and
17 polishing off top portions of the second conductive material, of the electrolyte layer, and
18 of the first conductive layer, which results in a planarized top surface of the ILD layer, of the first
19 conductive layer, of the electrolyte layer, and of the second conductive material, wherein a
20 conductive contact is formed on the planarized top surface, wherein the conductive contact is in
21 conductive contact with the second conductive material, wherein the first conductive
22 metallization includes the conductive plate, and wherein the second conductive metallization
23 includes the conductive contact, and wherein a U-battery With Double Extension has been
24 formed from the first conductive layer as the first electrode, the electrolyte layer as an electrolyte,
25 and the second conductive material as the second electrode.

1 24. The method of claim 23,

2 wherein the first electrode is selected from the group consisting of an anode and a
3 cathode;

4 wherein if the first electrode is an anode, then the second electrode is a cathode, the first
5 conductive layer includes an anode material, and the second conductive material includes a
6 cathode material; and

7 wherein if the first electrode is a cathode, then the second electrode is an anode, the first
8 conductive layer includes a cathode material, and the second conductive material includes an

9 anode material.

1 25. The method of claim 24, wherein the anode material is selected from the group consisting of
2 lithium and lithiated vanadium oxide ($\text{Li}_3\text{V}_2\text{O}_5$), wherein the cathode material includes V_2O_5 , and
3 wherein the electrolyte layer includes lithium phosphorous oxynitride.

1 26. The method of claim 23,
2 wherein forming an exposed insulating layer in the wiring level I and an exposed
3 conductive plate in the dielectric layer comprises: forming an etch stop layer on the exposed first
4 conductive plate and on the exposed insulating layer, and forming the ILD layer on the etch stop
5 layer; and

6 wherein forming a first trench within the ILD layer further comprises removing a portion
7 of the etch stop layer to expose the portion of the first conductive plate.

1 27. The method of claim 15, wherein forming at least one battery includes forming a first battery,
2 wherein forming a first battery, forming a first conductive metallization, and forming a second
3 conductive metallization comprises:

4 forming an exposed insulating layer in the wiring level I and an exposed first conductive
5 plate in the dielectric;

6 forming a first conductive layer on the insulating layer such that the first conductive layer
7 is in conductive contact with the first conductive plate;

8 forming an electrolyte layer on the first conductive layer, wherein the electrolyte layer
9 includes electrolyte materials; and

10 forming a second conductive layer on the electrolyte layer, wherein the second
11 conductive layer includes a second conductive material, wherein the first conductive
12 metallization includes the first conductive plate, and wherein a S-battery has been formed from
13 the first conductive layer as the first electrode, the electrolyte layer as an electrolyte, and the
14 second conductive layer as the second electrode.

1 28. The method of claim 27, wherein the first electrode is selected from the group consisting of
2 an anode and a cathode;

3 wherein if the first electrode is an anode, then the second electrode is a cathode, the first
4 conductive layer includes an anode material, and the second conductive layer includes a cathode
5 material; and

6 wherein if the first electrode is a cathode, then the second electrode is an anode, the first
7 conductive layer includes a cathode material, and the second conductive layer includes an anode
8 material.

1 29. The method of claim 28, wherein the anode material is selected from the group consisting of
2 lithium and lithiated vanadium oxide ($\text{Li}_8\text{V}_2\text{O}_5$), AgI, Ag and Zn, and wherein the cathode
3 material is selected from the group consisting of V_2O_5 , LiMn_2O_4 , LiCoO_2 , Sn, Pb and Ag, and
4 wherein an electrolyte of the first battery includes lithium phosphorous oxynitride.

1 30. The method of claim 27, further comprising:

2 forming an inter-level dielectric (ILD) layer on the second conductive layer;

3 forming a trench within the ILD layer by removing a portion of the ILD layer, which

4 exposes a portion of the second conductive layer;
5 overfilling the trench with a third conductive material; and
6 polishing off top portions of the third conductive material, which results in a planarized
7 top surface of the ILD layer and of the third conductive material, wherein a second conductive
8 plate is formed from the third conductive material on the planarized top surface, wherein the
9 second conductive plate is in conductive contact with the second conductive layer, and wherein
10 the second conductive metallization includes the second conductive plate.

1 31. The method of claim 15, wherein forming the at least one battery includes forming a plurality
2 of batteries in series.

1 32. The method of claim 31, wherein the batteries in series consist of U-Batteries in series.

1 33. The method of claim 31, wherein the plurality of batteries includes M batteries denoted as
2 batteries 1, 2, ..., M, wherein M is at least 2, wherein each battery L is in series with battery L+1
3 and is conductively coupled to battery L+1 by a conductive interconnect, and wherein L = 1, 2,
4 ..., M-1.

1 34. The method of claim 31, wherein the plurality of batteries includes M batteries denoted as
2 batteries 1, 2, ..., M, wherein M is at least 2, wherein each battery L is in series with battery L+1
3 and is conductively coupled to battery L+1, wherein there is no conductive interconnect between
4 battery L and battery L+1, and wherein L = 1, 2, ..., M-1.

35. The method of claim 15, wherein forming the at least one battery includes forming a plurality of batteries in parallel.

36. The method of claim 15, wherein forming a first conductive metallization includes forming a first conductive contact that conductively contacts the first electrode, wherein forming a second conductive metallization includes forming a second conductive contact that conductively contacts the second electrode, wherein the first conductive contact is within the wiring levels I, I+1, ... K, and wherein the second conductive contact is within the wiring levels I, I+1, ... K.

37. The method of claim 36, wherein $K = I$.

38. The method of claim 15, wherein forming a first conductive metallization includes forming a first conductive contact that conductively contacts the first electrode, wherein forming a second conductive metallization includes forming a second conductive contact that conductively contacts the second electrode, wherein the first conductive contact is outside of the wiring levels I, I+1, ... K, and wherein the second conductive contact is outside of the wiring levels I, I+1, ... K.

39. The method of claim 15, wherein forming the at least one battery includes forming a first battery, wherein an anode of the first battery includes an anode material selected from the group consisting of lithium, lithiated vanadium oxide ($\text{Li}_x\text{V}_2\text{O}_5$), AgI, Ag, and Zn, and wherein a cathode of the first battery includes a cathode material selected from the group consisting of V_2O_5 , LiMn_2O_4 , LiCoO_2 , Sn, Pb, and Ag, and wherein an electrolyte of the first battery includes

6 lithium phosphorous oxynitride.

1 40. The method of claim 15, wherein forming the at least one battery includes forming a U-
2 Battery.

1 41. The method of claim 40, wherein the U-Battery is a U-Battery With Double Extension.

1 42. The method of claim 15, wherein forming the at least one battery includes forming a S-
2 Battery.

1 43. The method of claim 15, wherein the step of forming a layer of electronic devices includes
2 forming the layer of electronic devices during a Front-End-Of-Line (FEOL) processing of the
3 integrated circuit, wherein the step of forming N wiring levels includes forming the N wiring
4 levels during a Back-End-Of-Line (BEOL) integration of the integrated circuit, wherein the step
5 of forming a first conductive metallization and a second conductive metallization includes
6 forming the first conductive metallization and the second conductive metallization during the
7 BEOL integration of the integrated circuit, and wherein the step of forming at least one battery
8 includes forming the at least one battery during the BEOL integration of the integrated circuit.